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ABSTRACT

This report analyzes recent trends in company-funded basic research support and incorporates findings from a special mail survey and personal interviews with research and development (R&D) officials of 54 firms. The report also provides insight into industry/university cooperative basic research efforts. Following an introduction, the report is organized into four sections. The first section presents highlights of major findings. The second section discusses trends in industrial basic research, focusing on trends by individual industry, factors responsible for increasing expenditures during 1975-81, basic research spending in 1982, factors responsible for declining expenditures during 1982, and impact of a decline in federal funding. Industrial funding of basic research at universities and colleges is discussed in the third section. A historical perspective (focusing on trends in industrial expenditures for basic research, and basic research expenditures by industry and by field of science and engineering) and four statistical tables are included in the appendices provided in the fourth section. Among the findings reported are those indicating increased company support of basic research performed at universities/colleges due to an apparent shift of academic research goals to areas of greater interest to industry and developments in biotechnology research requiring skills not available in industrial laboratories. (JN)

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foreword

There is widespread belief that information emanating from basic research is of major importance to the industrial innovation process. Although it is difficult to trace precisely the chain of events and to measure the linkages throughout the entire innovation process, there is growing acceptance that investment in basic research eventually yields a profitable return. This report analyzes recent trends in company-funded basic research support and incorporates the findings from a special mail survey and personal interviews with R&D officials of 54 firms. The report also provides insight into another area of growing interest—industry/university cooperative basic research efforts.

Charles E. Falk, Director
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Technological, and
International Affairs

acknowledgments

This report was prepared in the Division of Science Resources Studies by Melissa Pollak and Margaret R. Grucza, under the direction of Thomas J. Hogan, Study Director, Industry Studies Group. William L. Stewart, Head, R&D Economic Studies Section, provided general guidance and direction.

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introduction

To obtain information on possible significant changes in industry's funding of basic research in 1981 and 1982, a query was sent in December 1981 to selected members of NSF's Industrial Panel on Science and Technology, requesting comments regarding industrial support of basic research, particularly within the context of the panelist's own industries. (See appendix C for a copy of this letter.) The questions focused on real changes in industrial support of basic research during 1981 and 1982. Approximately 20 percent of the respondents expressed opinions on overall industrial spending on basic research; the remaining R&D officials restricted their comments to basic research funding within their own industries or companies during 1981 and/or 1982. The objective of the survey was to obtain comments from knowledgable individuals representing a cross section of industries. It is believed that this was accomplished. Responses were received from 44 panelists and additional information was obtained during regularly scheduled site visits with company R&D officials. Although the findings should not be considered statistically valid, responses were received from firms in all major basic research-performing industries. These firms accounted for approximately 50 percent of total company basic resarch expenditures in 1981. Nonrespondents were primarily from medium-sized and smaller firms in industries not heavily dependent on basic research.

highlights

The statistical data presented in this report were collected for the National Science Foundation (NSF) by the Bureau of the Census in the Annual Survey of Industrial Research and Development. Additional information, obtained between December, 1981, and March 1982, is based on 44 mail responses to an NSF inquiry to its Industrial Panel on Science and Technology and on ten interviews with R&D officials. The panelists and the other respondents represent companies in all the major basic research performing industries. These firms accounted for approximately 50 percent of all company-financed expenditures on basic research in 1981. The comments discussed in this report, unless otherwise indicated, are solely those of the respondents.

- In 1981, companies spent $1.3 billion of their own funds on basic research projects, approximately 4 percent of total industry-financed expenditures on research and development. There has been a continuous upward trend in industry's investment in basic research since 1975; the average annual rate of growth was 6.7 percent in constant dollars between 1975 and 1981. This rate of growth was about the same as the 6.5-percent increase in industrial funds spent on applied research and development during the same period.

- Information received from R&D officials indicated that the upward trend in basic research funding would slow considerably in 1982, increasing less than 3 percent in real terms. Nearly one-half the respondents reported that their firms' 1982 expenditures were expected to remain even with the level spent the previous year, when measured in constant dollars. Only firms in the chemicals industry were expected to increase their basic research outlays; real increases ranging from 5 percent to 10 percent were reported. R&D officials representing the remaining firms stated that their companies' investment in fundamental research activities would decline in real terms. The decreases ranged from 1 percent to 5 percent.

- Reasons cited by the respondents for the decline or lack of real growth in overall basic research expenditures during 1982 include expectations of decreased earnings and the need to channel scarce research dollars into shorter term profit-improvement programs, and high inflation and interest rates that create an unfavorable climate for capital formation.

- The two industries which lead in company-financed basic research expenditures are chemicals and electrical equipment. In 1981, $460 million was spent by firms in the chemicals industry, while companies in the electrical equipment industry spent $230 million. The average annual real rate of growth in expenditures on fundamental research projects was 14 percent in the chemicals industry between 1979 and 1981, the electrical equipment industry, in contrast, exhibited an average annual real decreases of 2 percent during the same period.

- Respondents from firms in the chemicals industry attribute this high rate of growth and the increase expected in 1982 to the exploration of recent biotechnology breakthroughs, particularly those related to genetic engineering. These officials also reported that firms in the chemicals industry have been expanding their basic research programs as they diversify into other areas—new to them but still classified within the chemicals industry—such as pharmaceuticals, agricultural chemicals, and energy feedstocks.

- The industries which rank third and fourth in company-financed expenditures on basic research are the petroleum and machinery industries. Both registered sizable increases, each averaging over 25 percent in constant dollars, in funding basic research between 1979 and 1981. Companies in the petroleum industry reported spending $133 million in 1981 on such basic research activities as improving fuel and engine efficiency and discovering new technologies relating to coal gasification, enhanced recovery, and solar energy. The machinery industry which spent $126 million in 1981 is financing fundamental research necessary to explore areas such as computer-aided design and computer-aided manufacturing technologies.

- Eighty-five percent of the responding firms fund basic research undertaken by universities and colleges. Two-thirds of that group either increased their support during 1981 or planned to increase it in 1982. Expenditures to support academic basic research, however, comprise less than 1 percent of the total company R&D budgets of almost all the reporting companies.

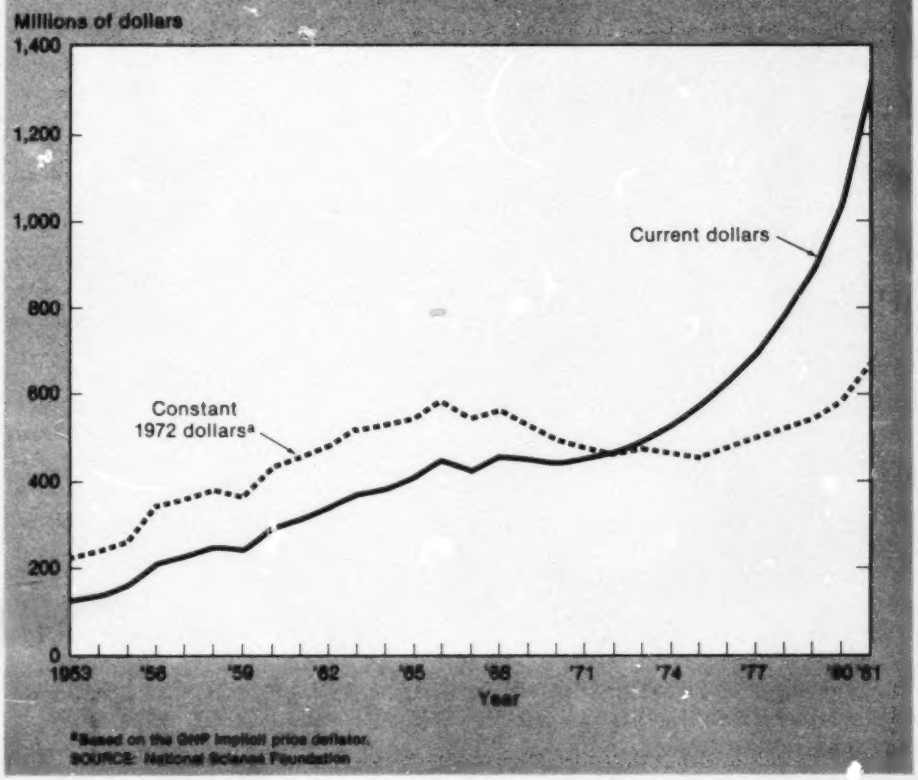
- Reasons given for increased company support of basic research performed at universities and colleges include an apparent shift of academic research goals to areas of greater interest to industry; new developments in biotechnology research requiring skills not available in industrial laboratories; and a recognition by many firms that a byproduct of funding academic research is the training of qualified scientists and engineers in fields which are important to industry.

trends in industrial basic research

Companies' expenditures of their own funds on basic research, measured in constant dollars, fell steadily throughout the late sixties and early seventies at an average annual rate of 2.8 percent between 1966 and 1975. This trend was reversed after 1975 as firms began to expand their in-house basic research programs. From 1975 through 1981, investment in basic research grew 6.7 percent per year in real terms, reaching a level of $1.3 billion in 1981. Only 4 percent of the total industry budget for research and development is used to support basic research projects; the remainder finances activities classified as applied research or development. Between 1975 and 1981 their funding levels grew at a pace about the same as that for basic research—6.5 percent after adjustment for inflation (chart 1).

Industry also receives funding from Federal agencies to perform in-house fundamental research activities. In 1981, the amount was $330 million. This report, however, addresses only that portion of industrial basic research financed internally. Appendix A contains more detailed background information on industry's performance of basic research.

Chart 1. Company funds for the performance of basic research



[a]Based on the GNP implicit price deflator.
SOURCE: National Science Foundation

by individual industry

The four industries leading in company-financed basic research expenditures in descending order are chemicals (460 million in 1981); electrical equipment ($230 million); petroleum refining ($133 million); and machinery (126 million). Between 1979 and 1981, the petroleum and machinery (which includes companies manufacturing office, computing, and accounting machines) and petroleum industries had the highest average annual growth rates in funds spent on fundamental research activities—over 25 percent in constant dollars for both industries.

Firms in the chemicals industry, however, accounted for nearly two-fifths the total increase in company funding occuring between 1979 and 1981. This industry had an average annual growth rate of 14 percent during that period. Of the four major basic research-performing industries, only the electrical equipment industry showed a lower growth rate than the all-industry average growth rate by declining 2 percent in real terms between 1979 and 1981.

factors responsible for increasing expenditures during 1975-81

Diversification, the birth of new industries, competition, and efforts to raise productivity were identified as the major factors spurring companies to increase their expenditures on basic research.

Corporate R&D officials from chemicals companies indicated that their firms are currently diversifying, most entering new product areas such as agricultural chemicals or drugs and medicines. The establishment of new product lines either through diversification and/or research innovation requires a high initial investment in basic research.

Almost every chemicals company respondent reported that basic research spending was increasing at an accelerating rate as their firms explored recent breakthroughs in biology and biochemistry, including genetic engineering. These areas are expected to yield lucrative commercial opportunities in the form of new products and processes embodying advances in biotechnology. In addition to the various segments of the chemicals industry, other areas including energy, forest products, and mining, will be affected by discoveries made through genetic research.

Intensifying domestic and foreign competition have caused an increase in the funding of basic research in some industries. (It should be noted, however, that these market forces have had an even greater impact on the performance of applied research and development.) This is particularly evident in the computer portion of the machinery industry and in the electronic components and communication equipment segments of the electrical equipment industry where basic research on computer-aided design, computer-aided manufacturing, information storage, and microprocessor technology is being performed. The emphasis on basic research in the semiconductor segment of the electrical equipment industry is continuing despite a recent recession in that industry. Fundamental research is deemed essential by these companies to ensure their future viability in a rapidly changing, high-technology industry.

Respondents from companies manufacturing other types of electrical equipment, however, reported cash flow problems attributable to poor sales. Ironically, foreign competition was blamed for that reduced income. Because of these financial constraints (which will be discussed in greater detail below), total company-financed expenditures on fundamental research activities by electrical equipment firms did not grow as rapidly as those made by companies in the other three major basic research-performing industries. R&D officials from the electrical equipment firms did report, however, that their companies' had been channeling scarce R&D resources into applied research and development at a faster rate than basic research as they sought to maximize the application of new technology by adding artificial intelligence capability and programmability to a continually widening range of products and processes.

Several respondents, including representatives from the food and petroleum industries, mentioned the importance of basic research in their efforts to raise productivity. Officials from petroleum companies reported that their basic research projects were aimed at improving the efficiency of engines and oil and gas production, utilizing lower quality feedstocks effectively, reducing operating costs, and discovering more economical methods of developing and producing alternative energy sources.

Economists have been investigating the impact of basic research on productivity. One study of 20 manufacturing industries indicates that a direct relationship exists between the amount of basic research undertaken by an industry or firm and its rate of increase in productivity. This finding provides evidence that, in general, the discoveries made through basic research are made operational exclusively by the industries and firms that undertook the work, or that successful basic research tends to complement and thus expedite applied R&D projects aimed at improving productivity.[1]

basic research spending in 1982

Aggregated information from the R&D officials indicates that in 1982 industrial expenditures on basic research will show ony a modest real gain, probably less than 3 percent. Nearly half the R&D officials willing to provide information on their own companies' expenditures for 1982 reported that internal funding of fundamental research activities would just keep pace with inflation; thus, there would be no change in their real levels of effort from 1981 to 1982. Responses from the remaining R&D officials indicated that only companies in the chemicals industry would expand their basic research programs in 1982—real increases of 5 percent to 10 percent were anticipated. Seven respondents reported real-dollar decreases, ranging from 1 percent to 5 percent. Officials

[1]Edwin Mansfield, "Basic Research and Productivity Increase in Manufacturing," *American Economic Review*, Vol. 70, No. 5, December 1980.

from many of the firms predicting either a reduction or no change in their constant-dollar expenditures between 1981 and 1982 stressed, however, that even during the current period of economic uncertainty, fundamental research programs were vital to their companies' survival and future prosperity. Therefore, their companies were committed to maintaining strong basic research programs.

factors responsible for declining expenditures during 1982

Almost half the respondents cited the recession for the curtailment of, failure to increase, or slowed growth of expenditures for basic research programs in 1982. In addition, high interest rates and inflation have deterred the performance of basic research by making it more expensive to purchase the capital equipment needed to conduct fundamental research and to obtain the capital necessary to incorporate research results into operations.

Further, the company R&D officials reported that decreased earnings from poor sales were creating severe cash-flow problems. This has limited the amount of discretionary funding available for basic research. Because it often requires a long-term commitment of financial resources and involves a high degree of risk, basic research is often one of the first areas to be cut back whenever stringent financial constraints must be imposed. In addition, any potential benefits from basic research usually are not readily apparent; profits from this type of project may not be realized until far in the future.

All of these factors combined have necessitated the postponement of many basic research projects until profitability is restored. As stated in a recent article,

> ...R&D is expensive. As technology has advanced, the equipment and brainpower needed in research have become increasingly sophisticated, forcing up R&D costs faster than general inflation. R&D is also risky; only a small minority of innovations attain commercial success. Even the successes reward their creators only in the distant future—ten years or longer for most significant developments. Potential profits must be huge to justify the risks and years of waiting, especially when towering interest rates and inflation require businessmen to deeply discount future earnings.[2]

The corporate R&D officials mentioned specific circumstances that in 1982 were having an adverse impact on the performance of basic research:

(1) Steel manufacturers were allocating financial resources to support plant and equipment modernization programs, which have been given a higher priority than basic research. It is anticipated that once these efforts have been completed, the firms will be able to compete more effectively with foreign manufacturers.

(2) Producers of equipment used in electric power generation were experiencing serious cash-flow problems and therefore curtailed their basic research programs. Demand for their products has decreased because of the failure of electric utility companies to obtain rate increases and, more important, to decreased energy use. Sales of nuclear additions to electric power generating systems have fallen sharply. With fewer sales, companies do not have the financial resources necessary to invest in more basic research.

(3) One-half the respondents from companies in the aircraft and missiles industry said that their firms were directing a greater portion of their research resources toward development programs to ensure short-term survival and growth. Anticipating increases in the procurement of new defense systems, firms in the industry expect to be able to maintain a constant level of effort in basic research to meet future needs. All the company officials from aerospace firms noted that the resources needed to finance exploratory research were too great to warrant the undertaking of basic research unless such an investment could be leveraged by government R&D contracts.

[2]Tom Alexander, "The Right Remedy for R&D Lag," *Fortune*, January 25, 1981.

Interviews with company R&D officials revealed that there is a trend toward longer term R&D projects; however, these projects may not necessarily be considered basic research. The increasingly complex nature of today's state-of-the-art technology has lengthened the time horizon needed to perform applied research or to develop a specific product or process. Officials in several industries, including the aerospace, discussed this aspect of R&D activity, explaining that a 10-year commitment is necessary even after the fundamental research has been completed.

impact of a decline in federal funding

With the exception of those in the aerospace industry, which has relied heavily on Federal funding for basic research activities, nearly all the corporate officials stated that the anticipated decline in Federal support of basic research would have little or no effect on their firms' funding of basic research. Several of these respondents qualified their answers, reporting that although there would be no short-term reaction, it was too soon to know if there would be long-range effects of such a spending reduction. In addition, respondents pointed out that the specifics of the Federal cuts were still unknown at the time they received the letter. Therefore, they were currently unable to determine if their companies would be affected by a reduction in Federal support of basic research. For example, it was noted that it had not yet been determined exactly which areas in basic energy research would be most affected.[3]

In the aerospace industry, a decrease in NASA technology base programs is

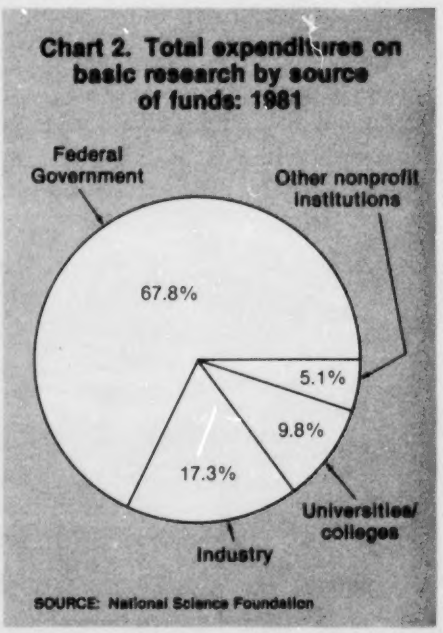
[3]Although a large cutback in total R&D budget authority for energy programs was proposed for 1982, the level actually reported for energy basic research programs remained constant in real terms between 1981 and 1982. See National Science Foundation, "Federal Basic Research Support in 1980-83 Grows at Slower Rate Than in Previous Four Years," *Science Resources Studies Highlights* (NSF 82-325) (Washington, D.C., September 30, 1982).

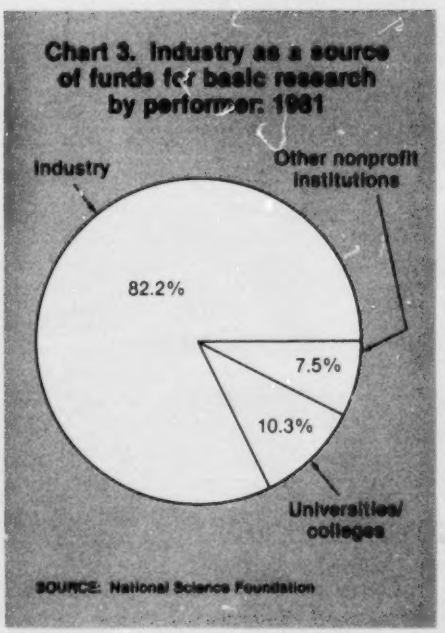
already having an adverse impact on the performance of basic research. Company officials from one-half the firms in this industry pointed out that they had reduced their funding of fundamental research activities, and will be forced to make further cutbacks, since internal financing in this industry parallels the pattern of Federal support, rather than the contrary, as is often assumed.

Several officials focused their remarks on the impact of possible reductions in Federal funding of basic research at academic institutions. The respondents mentioned that these anticipated cutbacks made them more keenly aware of the overall problems in universities and colleges. Although firms are placing greater emphasis on supporting academic basic research (discussed in more detail in the next section), the current economic climate is precluding them from making larger financial commitments. Overall, the corporate officials do not expect the private sector to provide the support necessary to compensate for a decline in federally funded basic research performed at academic institutions.

industrial funding of basic research at universities and colleges

In recent years, numerous changes have occurred in both the level of activity and the types of cooperative research programs undertaken by industry and universities. An examination of the industrial sector as a source of funds for basic research reveals that industry provided 17 percent of the total amount of funds expended for fundamental research activities in the United States in 1981 (chart 2).[4] Of these funds, a total of $1.3 billion, or over 80 percent, was for basic research projects undertaken in-house (chart 3). Funding by firms of fundamental research undertaken at universities and colleges totaled $164 million, or about 4 percent of total expenditures on basic research made by academic institutions in 1981 (chart 4). This was 10 percent of total industrial funding of basic research but amounted to less than 1 percent of all company-performed R&D activities during 1981 (chart 5).



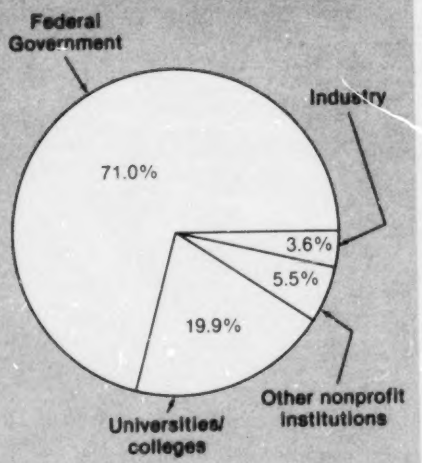


Forty-seven of the R&D officials responding to the letter or interviewed answered questions pertaining to industrial support of basic research performed by universities and colleges. All but six replied that their companies were, as of January 1982, financing this type of activity. Over half of these affirmative responses estimated their level of funding to be either 1 percent or less of their companies' total R&D budgets. Respondents from seven firms reported expenditures exceeding 1 percent, with one official estimating support at 4 percent, the highest portion mentioned.

Two-thirds of all the respondents (including some who said that their firms did not finance any ongoing basic research activities at academic institutions) mentioned that their companies had plans to increase expenditures in this area or that they expected their industries to increase expenditures in the near future. Two company R&D officials reported that their firms would probably decrease funding (no one mentioned a decline in a specific industry's expenditures), and six responded that their firms planned no change in their current level of financial support. Several respondents stated that funding of basic research performed by universities

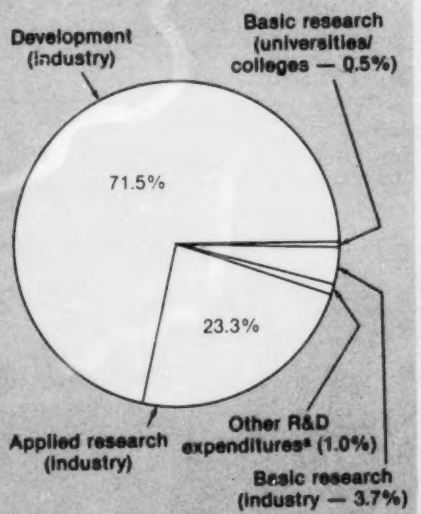
[4]National Science Foundation, *National Patterns of Science and Technology Resources, 1982* (NSF 82-319) (Washington, D.C.: Supt. of Documents, U.S. Government Printing Office, 1982).

Chart 4. Basic research expenditures by universities/ colleges by source of funds: 1981



SOURCE: National Science Foundation

Chart 5. Company R&D funds by character of work and by performer: 1981



[a]Includes industrial funding of research and development performed by other nonprofit institutions and industrial funding of applied research and development performed by universities/colleges.
SOURCE: National Science Foundation

and colleges, like other budgetary items, often depended on the firm's current financial position and is adversely affected if the economic climate is unfavorable.

The most frequently cited reason for the rise in collaborative basic research programs is the heightened interest and cooperation being shown by university and college researchers. In the past, researchers were reluctant to participate with companies in research projects; however, firms are currently detecting a change in this attitude. Many academic institutions are experiencing or anticipating a curtailment in funding from traditional government sources and are thus seeking stable, alternative sources of support. Consequently, they are shifting the focus of some of their research activities to areas of greater interest to industry in order to attract this potential source of funding.

One-fourth of the company R&D officials said they regarded the academic community as a leading source of new scientific ideas, which is particularly important when exploring new technical areas in which their firms do not have active programs or adequate staffing. Funding high-risk ventures outside the firm is often more cost-effective than incurring start-up costs, including the cost of additional technical personnel.

Forty percent of the R&D officials from chemicals companies said that recent biotechnology breakthroughs in genetic engineering have necessitated their tapping academic expertise to obtain skills currently unavailable in their firm's laboratories.

One of the most common arrangements to fund basic research at universities is the use of consulting contracts with individual university researchers. Industry R&D scientists and engineers are often familiar with research being undertaken by their former colleagues at academic institutions, and they also interact with university faculty at conferences. Thus, a one-to-one relationship is established through an informal network, and the company officials then know whom to contact when a specific area needs to be studied.

In addition, R&D officials interviewed stated that they were receiving a larger number of unsolicited proposals from university researchers. Some of these have resulted in small contracts for basic research. Some firms have chosen to fund these projects on an ad hoc basis, while others have set up more formal grants programs.

There are also a number of multifirm cooperative research programs, including some that involve funding basic research at universities. NSF has sponsored several of these collaborative ventures. In addition, firms in a number of industries have established organizations to serve as catalysts for cooperative research activities. Until recently, companies were inhibited from forming such associations by the potential threat of antitrust action. In 1980, the Justice Department delineated its position on such cooperative research ventures: They do not violate antitrust laws if all firms that want to participate in a venture are permitted to do so and if only long-term basic research is jointly financed and performed. Two of these industrial groups are the Council for Chemical Research and the Semiconductor Research Cooperative.

The Council for Chemical Research is a cooperative organization consisting of the largest companies in the chemicals industry and major universities. Two of the principal goals of the Council are to increase the amount of basic research funding that the chemical industry provides to academic institutions and to improve graduate education programs.

The Semiconductor Research Cooperative, initiated by the Semiconductor Industry Association, is an organization made up of the largest U.S. computer manufacturers and their semiconductor suppliers. The members will jointly provide financing, furnish equipment, and lend technical R&D personnel to universities and research centers to conduct research on projects that ordinarily would be too complex and/or expensive for an individual company or academic institution to undertake. Areas in which basic research will be performed include very large-scale integration, silicon lithography, and computer-aided design. In addition, it is anticipated that this increased flow of resources into university laboratories conducting basic research will lead to a greater supply of qualified scientists and engineers available to work in industry.

State governments, expressing interest in providing financial support, are facilitating the establishment of research institutes to house industry/university collaborative projects. In one plan, the State would receive a portion of any royalties from patents obtained through the research and, more important, the State would benefit from the jobs created by participating companies and by firms attracted to the area.[5]

[5] "R.P.I. Center Proposed for Industrial Research," *New York Times*, January 27, 1982.

appendixes

a. historical perspective
b. statistical tables
c. reproduction of covering letter

appendix a

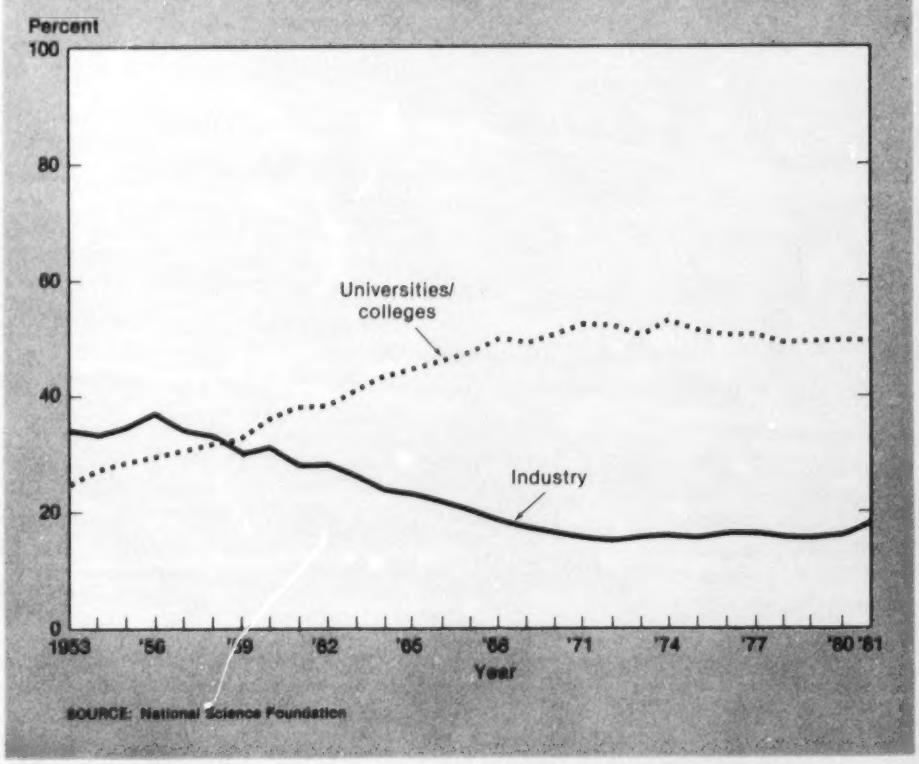
historical perspective

trends in industrial expenditures for basic research

The National Science Foundation's survey of industrial research and development uses the following definition of basic research: original investigations for the advancement of scientific knowledge that do not have specific commercial objectives, although they may be in a field or fields of present or potential interest to companies.

The contribution of the industrial sector to both the national level of expenditures for, and the actual performance of basic research fell steadily during the sixties from approximately 30 percent in 1960 to around 16 percent in 1971. It remained at approximately that level through 1981.[1] A combination of several factors caused the proportion of total basic research activities accounted for by companies to diminish during the sixties. The university and college sector accounted for 36 percent of total expenditures for the performance of basic research in 1960. Educational institutions obtain most of their funding—historically around 70 percent—from government agencies. Federal funding of basic research projects performed at universities and colleges grew at a significantly faster pace than industrial expenditures throughout the sixties. Thus, by 1970 the universities' and colleges' share rose to 51 percent of U.S. basic research activities and the industrial share fell to (and remains at) its current level (chart B-1).

Chart B-1. Expenditures for the performance of basic research by industry and by universities/colleges as a percent of total basic research funding



[1]National Science Foundation, *National Patterns of Science and Technology Resources, 1982, op. cit.*

In contrast to this expansion in Federal support for basic research undertaken at academic institutions, government financing provided to companies for fundamental research, measured in constant dollars, decreased during the same period. Between 1962 and 1973, Federal support of industrial basic research activities fell at an average annual rate of approximately 4.3 percent, in real terms, largely a result of curtailments in defense and space programs (chart B-2).

Of the total amount of funding that the government supplies to industry to undertake R&D projects—$16.5 billion in 1981—only 2 percent goes into basic research, while 14 percent is used for applied research and 84 percent for development. Although companies provided only a slightly higher proportion of their own funds to basic research activities (4 percent), the absolute dollar amount was four times that of Federal support for industrial basic research. Applied research consumed 23 percent and development programs received 73 percent of total private investment—$35.4 billion—in industrial R&D activities in 1981 (chart B-3).

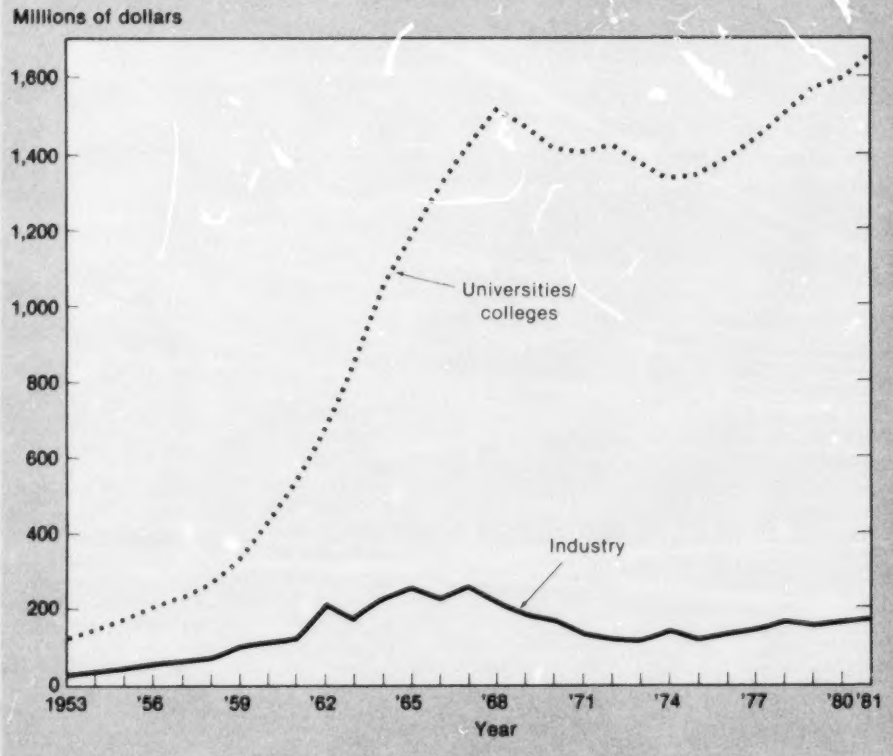
The total amount (including Federal funds) spent by companies to perform basic research in 1981 was $1.6 billion. When measured in constant dollars, however, this level was only 3 percent above that reported in 1966. Real performance of industrial basic research began to fall after 1966 and continued to decline through 1975 at an average annual rate of 3.7 percent. A study funded by NSF[2] revealed several factors contributing to this downward trend:

(1) One of the results of an evolution in R&D management that occurred during this period was the imposition of more stringent controls on the innovation process by mandating that R&D projects have clearly defined objectives. Many risky, long-term ventures failed to pass this scrutiny and thus were discarded or postponed in favor of more goal-oriented projects.

(2) Government support decreased for basic research performed by private industry, and government regulation increased. Complying

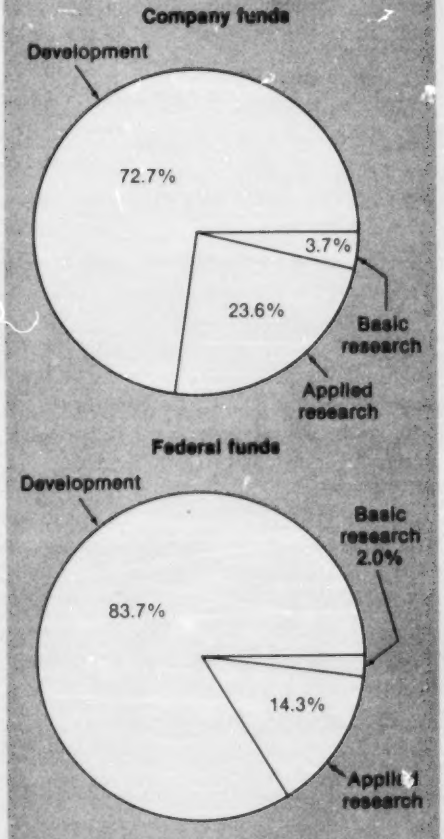
[2]National Science Foundation, *Support of Basic Research by Industry*, Report prepared for NSF by Howard K. Nason, Industrial Research Institute Research Corporation and Joseph A. Steger and George E. Manners, Rensselaer Polytechnic Institute under Grant NSF-C76-21517 (Washington, D.C., 1978).

Chart B-2. Federal funding of basic research performed by industry and by universities/colleges in constant 1972 dollars



SOURCE: National Science Foundation

Chart B-3. Industrial R&D expenditures by source of funds — percent devoted to basic and applied research and development: 1981



SOURCE: National Science Foundation

with the latter drained the amount of funds available for basic research.[3]

(3) Applied research and development received heavier emphasis. [This is discussed in more detail below.]

(4) Growing pressure on profits necessitated the investment in low-risk, short-term projects likely to yield immediate payoffs.

This trend was reversed between 1975 and 1981, when industrial outlays for basic research projects increased nearly 50 percent in real terms. Renewed optimism about the long-range potential profitability from investing in basic research and the growing threat of competition from abroad in technology-intensive industries were factors instrumental in triggering this upsurge.[4]

Despite the sizable increase in basic research during the second half of the seventies, until the eighties this growth was insufficient to arrest the gradual decline in the proportion of total company R&D expenditures devoted to basic research. The ratio fell from approximately 6.7 percent in 1960 to 3.7 percent in 1974, fell to 3.4 percent in 1980 and then rose to 3.7 percent in 1981 (chart B-4).

The deemphasis on basic research relative to the other two types of R&D activity between 1960 and 1980 occurred as industry began to stress short-term returns from its R&D investment. Given the risk associated with research and development and increasing financial pressures, industry had been concentrating its resources more intensively on applied research and development because these activities lead to more rapid commercialization of specific products or improved processes. In addition, companies had been taking advantage of a substantial accumulation of scientific knowledge from basic research performed in earlier years that had not been fully exploited. A wide range of assorted products based on those technological advances could be successfully developed and marketed. There was no incentive to perform more basic research because many companies did not have sufficient resources to market products based on technology already in existence so that any further advances emerging from additional research would have to be shelved.[5]

Thus, during the sixties and most of the seventies basic research may have been relegated to a less important status within the entire innovation process.

basic research expenditures by industry and by field of science and engineering

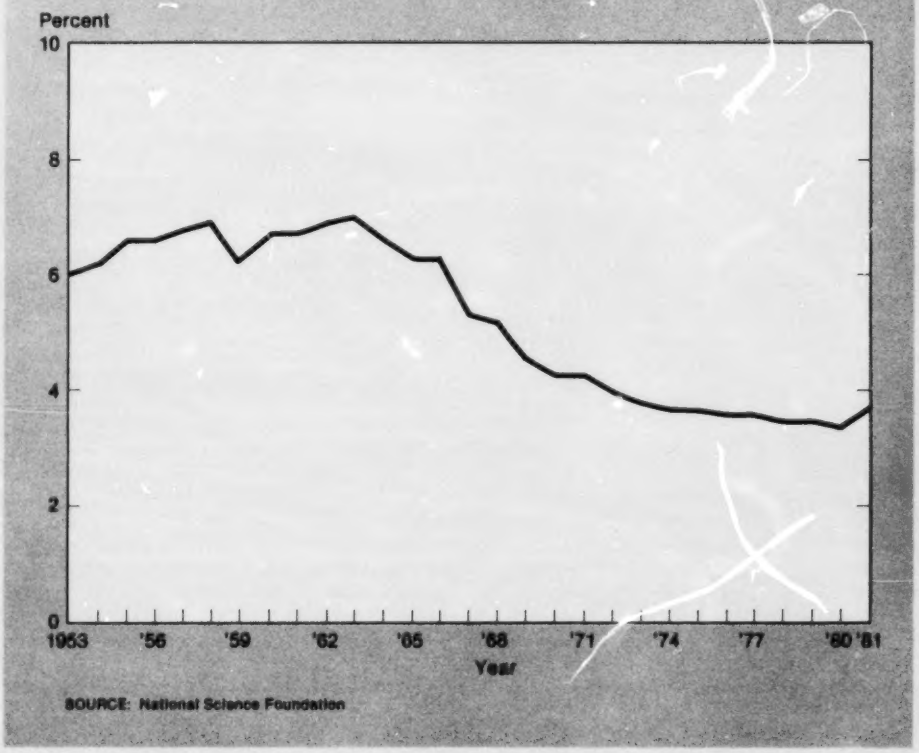
Industrial basic research is an enormously concentrated activity—only a very small number of firms perform most of the basic research undertaken by industry in the United States. In 1981, just 10 companies accounted for nearly half of all funds (in-

[3] Although the company R&D officials interviewed in this study mentioned increased government regulation as an important factor leading their firms to cut back expenditures on basic research, there is not complete agreement on the validity of this assertion. Frank Healy in a recent article entitled "Industry Needs for Basic Research" (*Research Management*, November 1978) pointed out that the deemphasis on basic research largely took place during the sixties before the existence of many government regulatory agencies. Thus, he concluded that the increase in government regulations was not a significant factor in the curtailment of industry's basic research programs.

[4] "Basic Research Outlays After years of Neglect," *Wall Street Journal*, September 3, 1981.

[5] Information from interviews with company R&D officials contained in National Science Foundation, *Support of Basic Research by Industrty, op. cit.*

Chart B-4. Company funds spent internally: proportion used to perform basic research



SOURCE: National Science Foundation

cluding Federal) expended by industry on basic research activities.

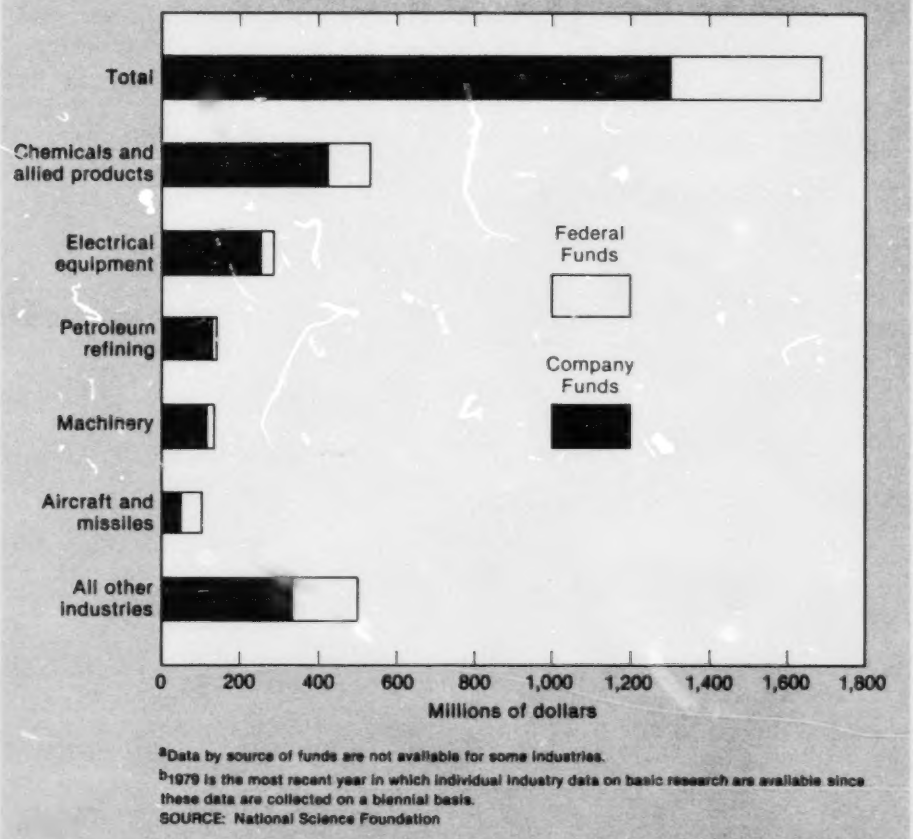
Nearly two-thirds of all spending on basic research from companies' own funds occurred in four industries. The chemicals industry historically has led in the performance of basic research; in 1981, it spent nearly one-third, or $539 million, of all the all-industry total. The electrical equipment, petroleum refining, and machinery industries accounted for 17 percent, 8 percent, and 8 percent, respectively, of total industrial expenditures for basic research.

The chemicals industry led in company-financed basic research, allocating $458 million, or 9 percent of its R&D budget, to basic research. The electrical equipment industry was second, spending $232 million, or 4 percent of its own R&D funds, on basic research in 1981.

Companies in the chemicals industry also received the highest allotment of Federal funds provided for basic research activities—$71 million, or 22 percent of the total amount of funds furnished by government agencies for industrial basic research in 1981 (chart B-5).

Almost half—$750 million—of total industrial basic research expenditures in 1981 was in the physical sciences. Of those funds, 72 percent was spent on projects classified within the field of chemistry. Engineering and the life sciences accounted for another 25 percent and 15 percent, respectively, of total industrial basic research expenditures.

Chart B-5. Industrial expenditures on basic research by industry and by sources of funds:[a] 1981[b]



[a]Data by source of funds are not available for some industries.

[b]1979 is the most recent year in which individual industry data on basic research are available since these data are collected on a biennial basis.

SOURCE: National Science Foundation

appendix b

statistical tables

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Table B-1. Funds for basic research, applied research, and development performance: 1953-81

[Dollars in millions]

Year	Total	Basic research	Applied research	Development
1953	3,630	$151	[1]$726	[1]$2,753
1954	4,070	166	[1]814	[1]3,090
1955	4,640	189	[1]928	[1]3,523
1956	6,605	253	1,268	5,084
1957	7,731	271	1,670	5,790
1958	8,389	295	1,911	6,183
1959	9,618	320	1,991	7,307
1960	10,509	376	2,029	8,104
1961	10,908	395	1,977	8,537
1962	11,464	488	2,449	8,527
1963	12,630	522	2,457	9,651
1964	13,512	549	2,600	10,362
1965	14,185	592	2,658	10,934
1966	15,548	624	2,843	12,081
1967	16,385	629	2,915	12,842
1968	17,429	642	3,124	13,663
1969	18,308	618	3,287	14,403
1970	18,067	602	3,427	14,038
1971	18,320	590	3,415	14,315
1972	19,552	593	3,514	15,445
1973	21,249	631	3,825	16,793
1974	22,887	699	4,288	17,900
1975	24,187	730	4,570	18,887
1976	26,997	819	5,112	21,066
1977	29,825	911	5,636	23,278
1978	33,304	1,035	6,300	25,969
1979	38,226	1,158	7,225	29,843
1980	44,505	1,325	8,450	34,730
1981	51,830	1,641	10,712	39,477

[1]Estimated by the National Science Foundation.

SOURCE: National Science Foundation

Table B-2. Funds for basic research, applied research, and development by industry and selected company size-groups: 1981

[Dollars in millions]

Industry and size of company	SIC code	Total	Basic research	Applied research	Develop-ment
Total	.....	$51,830	$1,641	$10,712	$39,477
Distribution by industry					
Food and kindred products	20	719	27	(1)	(1)
Textiles and apparel	22,23	124	1	31	92
Lumber, wood products, and furniture	24,25	167	(1)	(1)	95
Paper and allied products	26	(1)	32	(1)	370
Chemicals and applied products	28	5,325	539	2,263	2,523
Industrial chemicals	281-82,286	2,553	335	1,113	1,105
Drugs and medicines	283	(1)	(1)	(1)	(1)
Other chemicals	284-85,287-89	(1)	24	(1)	456
Petroleum refining	29	(1)	(1)	(1)	989
Rubber products	30	(1)	23	(1)	(1)
Stone, clay, and glass products	32	(1)	(1)	(1)	307
Primary metals	33	889	46	341	502
Ferrous metals and products	331-32,3398-99	(1)	(1)	(1)	(1)
Nonferrous metals and products	333-36	(1)	16	(1)	(1)
Fabricated metals products	34	638	8	153	477
Machinery	35	6,800	128	1,252	5,420
Office, computing, and accounting machines	357	(1)	(1)	(1)	3,611
Other machinery, except electrical	351-56,358-59	(1)	(1)	(1)	1,809
Electrical equipment	36	10,466	279	1,782	8,405
Radio and TV receiving equipment	365	(1)	(1)	132	(1)
Communication equipment	366	4,737	(1)	(1)	3,774
Electronic components	367	1,659	(1)	285	(1)
Other electrical equipment	361-64,369	(1)	(1)	(1)	2,803
Motor vehicles and motor vehicles equipment	371	4,929	(1)	(1)	(1)
Other transportation equipment	373-75,379	(1)	(1)	(1)	77
Aircraft and missiles	372,376	11,702	128	1,451	10,123
Professional and scientific instruments	38	3,685	40	444	3,201
Scientific and mechanical measuring instruments	381-82	(1)	(1)	248	(1)
Optical, surgical, photographic, and other instruments	383-87	(1)	(1)	(1)	(1)
Other manufacturing industries	21,27,31,39	393	21	(1)	(1)
Nonmanufacturing industries	07-17,41-67, 737,739,807,891	(1)	(1)	865	1,094
Distribution by size of company (based on number of employees)					
Less than 1,000	.....	2,522	153	715	1,654
1,000 to 4,999	.....	3,213	179	1,066	1,968
5,000 to 9,999	.....	2,425	118	607	1,700
10,000 to 24,999	.....	6,938	229	2,125	4,584
25,000 or more	.....	36,732	962	6,199	29,571

(1) Not separately available but included in total.

SOURCE: National Science Foundation

Table B-3. Funds for basic research, applied research, and development by industry, source of funds, and selected company size-groups: 1981

[Dollars in millions]

Industry and size of company	SIC code	Federal				Company			
		Total	Basic research	Applied research	Development	Total	Basic research	Applied research	Development
Total		$16,468	$328	$2,353	$13,787	$35,362	$1,313	$8,359	$25,690
Distribution by industry									
Food and kindred products	20	6	0	(1)	(1)	713	27	287	399
Textiles and apparel	22,23	1	0	1	0	123	1	30	92
Lumber, wood products, and furniture	24,25	0	0	0	0	167	(1)	(1)	95
Paper and allied products	26	(1)	0	(1)	0	562	32	160	370
Chemicals and applied products	28	383	81	134	168	4,942	458	2,129	2,355
Industrial chemicals	281-82,286	367	(1)	123	163	2,186	254	990	942
Drugs and medicines	283	(1)	(1)	(1)	5	1,997	(1)	(1)	(1)
Other chemicals	284-85,287-89	(1)	0	(1)	0	759	24	279	456
Petroleum refining	29	(1)	(1)	(1)	(1)	1,777	133	751	892
Rubber products	30	(1)	(1)	(1)	(1)	616	(1)	(1)	(1)
Stone, clay, and glass products	32	(1)	(1)	(1)	(1)	411	16	125	270
Primary metals	33	182	0	10	172	707	46	331	330
Ferrous metals and products	331-32,339 pt-99	(1)	0	(1)	(1)	414	(1)	180	203
Nonferrous metals and products	333-36	(1)	0	(1)	(1)	293	16	151	126
Fabricated metals products	34	80	0	12	68	558	8	141	409
Machinery	35	739	2	224	513	6,061	126	1,028	4,907
Office, computing, and accounting machines	357	(1)	(1)	(1)	(1)	3,919	(1)	(1)	3,228
Other machinery, except electrical	351-56,358-59	(1)	(1)	(1)	(1)	2,142	(1)	(1)	1,679
Electrical equipment	36	3,962	47	446	3,470	6,502	232	1,336	4,935
Radio and TV receiving equipment	365	(1)	0	(1)	(1)	364	(1)	(1)	(1)
Communication equipment	366	1,791	(1)	(1)	1,597	2,946	(1)	(1)	(1)
Electronic components	367	376	(1)	(1)	(1)	1,282	(1)	268	1,004
Other electrical equipment	361-64,369	(1)	(1)	(1)	(1)	1,910	(1)	(1)	1,499
Motor vehicles and motor vehicles equipment	371	634	(1)	(1)	602	4,295	21	(1)	(1)
Other transportation equipment	373-75,379	(1)	(1)	(1)	(1)	86	(1)	(1)	48
Aircraft and missiles	372,376	8,501	59	877	7,566	3,201	69	574	2,557
Professional and scientific instruments	38	638	5	41	592	3,047	(1)	403	(1)
Scientific and mechanical measuring instruments	381-82	(1)	(1)	(1)	(1)	1,285	(1)	210	(1)
Optical, surgical, photographic, and other instruments	383-87	(1)	(1)	(1)	(1)	1,762	22	(1)	(1)
Other manufacturing industries	21,27,31,39	0	0	0	0	393	21	(1)	(1)
Nonmanufacturing industries	07-17,41-67, 737,739,807,891	(1)	(1)	523	287	1,199	50	342	807
Distribution by size of company (based on number of employees)									
5,000 to 9,999		559	1	97	461	1,866	117	510	1,239
10,000 to 24,999		1,253	58	246	949	5,685	171	1,879	3,635
25,000 or more		13,661	225	1,653	11,783	23,071	737	4,546	17,788

[1] Not separately available but included in total.

SOURCE: National Science Foundation

Table B-4. Funds for basic research by industry and size of company: 1957-58, 1963-77, 1979, and 1981

[Dollars in millions]

Industry and size of company	SIC code	'1957	'1958	1963	1964	1965	1966	1967	1968	1969
Total	.....	$271	$295	$522	$549	$592	$624	$629	$642	$618
Distribution by industry										
Food and kindred products	20	4	5	12	14	10	13	17	16	16
Textiles and apparel	22,23	1	1	1	[2]	[2]	1	2	2	2
Lumber, wood products, and furniture	24,25	0	0	0	[2]	[2]	0	0	[2]	[2]
Paper and allied products	26	1	[2]	2	2	3	4	4	4	4
Chemicals and applied products	28	82	92	152	153	173	176	184	202	208
Industrial chemicals	281-82,286	[2]	[2]	105	105	119	[2]	[2]	[2]	[3]
Drugs and medicines	283	18	21	33	35	38	45	45	60	67
Other chemicals	284-85,287-89	6	6	14	[2]	[2]	9	14	14	14
Petroleum refining	29	35	34	34	37	34	29	36	37	38
Rubber products	30	4	[2]	8	[2]	[2]	5	5	6	3
Stone, clay, and glass products	32	[3]	[3]	6	5	9	[2]	[2]	[2]	[2]
Primary metals	33	6	7	11	11	13	12	13	14	16
Ferrous metal and products[4]	331-32,3398-99	5	5	8	8	10	[2]	[2]	[2]	[2]
Nonferrous metals and products[4]	333-36	[2]	2	3	3	3	3	4	5	8
Fabricated metals products	34	1	1	5	4	4	4	3	3	3
Machinery	35	17	20	25	26	22	26	26	31	21
Office, computing, and accounting machines	357	[5]	[5]	[5]	[5]	[5]	[5]	[5]	[5]	[5]
Other machinery, except electrical	351-56,358-59	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]
Electrical equipment	36	53	63	133	134	148	122	131	134	133
Radio and TV receiving equipment	365	[7]	[7]	[7]	[7]	[7]	[7]	[2]	[2]	[2]
Electronic components	367	36	43	110	112	121	96	112	15	117
Communication equipment	366									
Other electrical equipment	361-64,369	17	21	23	22	27	[2]	[2]	[2]	[2]
Motor vehicles and motor vehicles equipment	371	5	[2]	28	38	37	[2]	[2]	[2]	[2]
Other transportation equipment	373-75,379									
Aircraft and missiles	372,376	25	26	59	68	74	74	73	70	65
Professional and scientific instruments	38	8	10	[2]	[2]	[2]	[2]	[2]	[2]	[2]
Scientific and mechanical measuring instruments	381-82	3	2	1	3	3	[2]	[2]	[2]	[2]
Optical, surgical, photographic, and other instruments	383-87	6	8	[2]	[2]	[2]	[2]	[2]	[2]	[2]
Other manufacturing industries	21,27,31,39	13	8	3	4	4	4	5	5	5
Nonmanufacturing industries	07-17,41-67, 737,739,807,891	[2]	[2]	28	25	29	51	52	45	43
Distribution by size of company (based on number of employees)										
Less than 1,000	.....	[2]	[2]	[2]	[2]	[2]	39	56	[2]	[2]
1,000 to 4,999	.....	24	32	31	34	40	67	45	[2]	[2]
5,000 to 9,999	.....	218	240	439	461	488	38	50	55	62
10,000 to 24,999	.....									
25,000 or more	.....						480	478	490	469

Table B-4. Funds for basic research by industry and size of company: 1957-58, 1963-77, 1979, and 1981 — Continued

[Dollars in millions]

Industry and size of company	SIC code	1970	1971	1972	1973	1974	1975	1976	1977	1979	1981
Total	.....	$602	$590	$593	$631	$699	$730	$819	$911	$1,158	$1,641
Distribution by industry											
Food and kindred products	20	16	15	13	11	9	10	18	20	17	27
Textiles and apparel	22,23	2	2	2	1	2	[2]	[2]	[2]	[2]	1
Lumber, wood products, and furniture	24,25	[2]	[2]	[2]	[2]	[2]	3	5	7	5	[2]
Paper and allied products	26	5	4	4	5	7	5	6	9	18	32
Chemicals and applied products	28	207	216	214	236	288	294	304	337	366	539
Industrial chemicals	281-82,286	[2]	118	117	125	157	154	154	163	197	335
Drugs and medicines	283	93	77	78	90	107	112	119	134	143	[2]
Other chemicals	284-85,287-89	18	21	19	21	24	27	32	40	[2]	24
Petroleum refining	29	26	21	22	26	33	36	44	48	74	[2]
Rubber products	30	5	4	6	3	5	4	7	9	18	23
Stone, clay, and glass products	32	[2]	14	18	20	21	32	38	41	40	[2]
Primary metals	33	18	17	9	8	9	14	16	14	24	46
Ferrous metals and products[4]	331-32,3398-99	[2]	[2]	[2]	[2]	[2]	4	5	5	12	[2]
Nonferrous metals and products[4]	333-36	8	[2]	[2]	[2]	[2]	10	12	9	16	16
Fabricated metals products	34	5	[2]	7	11	3	5	2	2	4	8
Machinery	35	21	22	24	24	28	32	56	57	66	128
Office, computing, and accounting machines	357	[5]	[5]	[2]	[2]	[2]	26	38	41	51	[2]
Other machinery, except electrical	351-56,358-59	[6]	[6]	[6]	[6]	[6]	[6]	18	16	15	[2]
Electrical equipment	36	139	138	137	143	143	132	163	181	228	279
Radio and TV receiving equipment	365	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]
Electronic components	367	122	120	10	8	5	4	5	6	7	[2]
Communication equipment	366			108	117	116	109	130	150	195	[2]
Other electrical equipment	361-64,369	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]
Motor vehicles and motor vehicles equipment	371	[2]	21	10	8	9	10	8	12	[2]	[2]
Other transportation equipment	373-75,379			[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]
Aircraft and missiles	372,376	63	50	62	58	57	54	54	55	88	128
Professional and scientific instruments	38	[2]	19	17	15	16	16	23	24	[2]	40
Scientific and mechanical measuring instruments	381-82	[2]	7	6	5	5	9	10	12	[2]	[2]
Optical, surgical, photographic, and other instruments	383-87	[2]	12	11	10	11	8	12	12	[2]	[2]
Other manufacturing industries	21,27,31,39	4	6	5	6	6	[2]	[2]	[2]	42	21
Nonmanufacturing industries	07-17,41-67, 737,739,807,891	38	31	28	28	26	25	29	44	57	[2]
Distribution by size of company (based on number of employees)											
Less than 1,000	.....	38	36	36	32	34	57	68	73	98	153
1,000 to 4,999	.....	58	51	45	58	47	34	52	55	69	179
5,000 to 9,999	.....	62	72	58	75	88	103	118	126	158	118
10,000 to 24,999	.....	444	431	90	98	102	96	138	166	211	229
25,000 or more	.....			364	368	428	440	443	491	622	962

[1] Estimated by the National Science Foundation.
[2] Not separately available but included in total.
[3] Data included in the other manufacturing industries group.
[4] SIC codes 3398 and 3399 included in the nonferrous metals and products group for 1957-65.
[5] Data not tabulated at this level prior to 1972.
[6] Data not tabulated at this level prior to 1975.
[7] Included in the other electrical equipment group.

SOURCE: National Science Foundation

appendix c

reproduction of covering letter

page

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NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

December 10, 1981

For the first time since the mid-seventies national basic research spending in 1981 is not expected to show real growth, after adjusting for inflation. This primarily reflects a decline in Federal basic research support, which accounts for about 70 percent of total national basic research expenditures.

Industrial spending for basic research activities in 1981 is expected to increase in real terms nearly 5 percent over 1980, which would continue the trend of an average annual increase in real terms of 5 percent between 1975 and 1980. This recent growth follows a 9 year period in which basic research spending by industry fell at an average annual rate of 2 percent.

The National Science Foundation is examining the current situation and trying to assess the role of the various sectors of the economy in supporting basic research activities. It is well-recognized that few companies use the category "basic research" for internal reporting and analytical purposes. Companies more often refer to this research as exploratory or fundamental, but it is the trends in industrial spending on this "type" of research that we are interested in.

In your capacity as a member of the Foundation's Industrial Panel on Science and Technology, your assistance is requested in improving our understanding of both the current status and the near-term future of company funds directed toward basic research. Specifically, has there been a 5 percent real growth in overall industrial basic research spending in 1981 as had been expected? (The economic climate during the year may have affected earlier estimates for this year's rate of growth in basic research.) Is basic research performance by companies in your industry going to show growth in 1982 (in either current or constant dollars)? What percentage change would you expect for your company and/or for the industry? What are some of the factors that have affected the planned level of an increase, decrease, or stable level? What effect, if any, will the anticipated decline in Federal support of basic research have in the planning of your company's, or industry's, basic research investment in 1982 or 1983?

There is a great deal of interest in university-industry cooperative research efforts. Our information indicates that the level of this type of activity has recently accelerated. Can you give us an indication of what proportion of your company R&D expenditures, if any, currently are targeted to fund university basic research efforts? If so, do you anticipate an increase in your company funds specifically directed to support basic research activities at universities? Please comment on the reasons for any changes.

Any additional information you may have on these basic research issues, based on your experience, would be greatly appreciated. Your comments will be most helpful to us if we receive them within the next 3-4 weeks.

Sincerely,

Thomas J. Hogan

Thomas J. Hogan
Study Director
Industry Studies Group
Division of Science
Resources Studies

other science resources publications

Science Resources Studies Highlights

R&D Funds

	NSF No.	Price
"Universities Spent 6% of Separately Budgeted R&D Expenditures for Research Equipment in 1980"	82-316	-----

S/E Personnel

	NSF No.	Price
"Projected Employment Scenarios Show Possible Shortages in Some Engineering and Computer Specialties"	83-307	-----
"Labor Market Slackens for New Science and Engineering Graduates"	82-330	-----
"Growth in Employment of Science and Engineering Doctorates Continues, Led by Computer Scientists"	82-328	-----
"Science/Engineering Doctorate Production Increases in 1981; More New Doctorates Seek Nonacademic Positions"	82-323	-----
"Employment of Recent Science and Engineering (S/E) Graduates in S/E Fields Increased"	82-320	-----
"Academic Science/Engineering Employment Increased 3% Between 1980 and 1981"	82-312	-----
"Labor Markets for New Science and Engineering Graduates in Private Industry"	82-310	-----
"Graduate Science/Engineering Enrollment Up 3% Between 1979 and 1980"	82-306	-----
"Growth in Scientific and Engineering Employment Slows Between 1978-80"	82-303	-----

Detailed Statistical Tables

S/E Personnel

	NSF No.	Price
Characteristics of Doctoral Scientists and Engineers in the United States: 1981	82-332	-----
U.S. Scientists and Engineers, 1980	82-314	-----
Characteristics of Recent Science/Engineering Graduates: 1980	82-313	-----
Academic Science: Scientists and Engineers, January 1981	82-305	-----
Academic Science: Graduate Enrollment and Support, Fall 1980	81-330	-----
Scientists, Engineers, and Technicians in Private Industry, 1980	81-329	-----
Federal Scientific and Technical Personnel: 1976, 1977, and 1978	81-309	-----
Scientists and Engineers From Abroad, 1976-78	80-324	-----

Reports

R&D Funds

	NSF No.	Price
Federal Funds for Research and Development, Fiscal Years 1980, 1981, and 1982, Volume XXX	82-321	$4.75
Problems of Small, High-Technology Firms	81-305	-----

S/E Personnel

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Activities of Science and Engineering Faculty in Universities and 4-Year Colleges, 1978/79	81-323	-----
Young and Senior Science and Engineering Faculty, 1980	81-319	-----
Foreign Participation in U.S. Science and Engineering Higher Education and Labor Markets	81-316	$4.50
Science and Engineering Employment: 1970-80	81-310	$2.75
The Stock of Science and Engineering Master's Degree-Holders in the United States	81-302	-----

Composite

	NSF No.	Price
Science and Engineering Personnel: A National Overview	82-318	$5.00
Academic Science: 1972-81. R&D Funds, Scientists and Engineers, Graduate Enrollment and Support	81-326	-----